THE UNIVERSITY OF MELBOURNE

# Improving Urban Environments with Green Infrastructure

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# ‘Dark clouds’ gathering in our urban centres

**High energy use**
Air-conditioners in offices, industry and homes

**Poor air quality**
Dust storm, and chemical pollution

**Food security**
Climate change threatens rural food production. Increased costs.

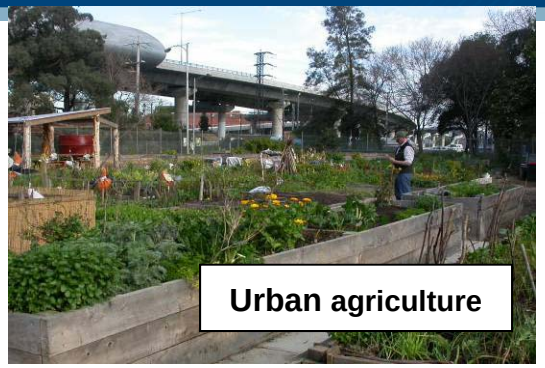
**Heat stress**
Heat-related illness and death. Poor city liveability.

**Flooding**
Extreme storm events lead to localised flooding

**Greenhouse gas**
Emissions from transport, construction and buildings

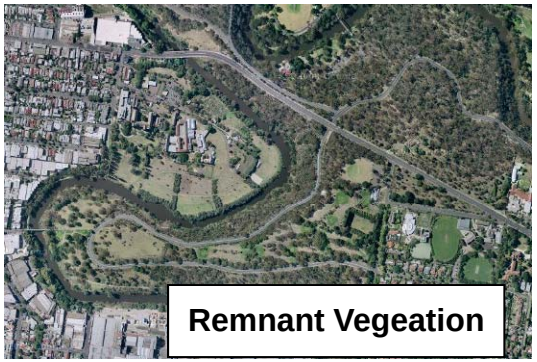
**Water quality**
Storm run-off threatens urban water ways

# Urban Green Infrastructure


Urban agriculture


Green walls

We can use green infrastructure to improve the built environment and provide ecosystem services and biodiversity habitat


Remnant Vegeation


WSUD


City street trees


Green roofs


Vegetated urban design


Parks, gardens & golf courses

# Benefits of Green Infrastructure

## Urban green infrastructure can provide:

### Environmental benefits

- **Direct C sequestration –** Plants & soil.
- **Urban heat island decrease** – Plants reflect sun's radiation, shade and transpire.
- **Reduced energy use –** Shade trees, green roofs and green walls.
- **Reduced stormwater run-off –** Canopy interception reduces flooding.
- **Pollution filter –** Foliage traps air particles
- **Water quality –** Improved river and bay.
- **Biodiversity –** Wildlife habitat provision

### Socio-economic benefits

- **Physical health** – Reduced respiratory illness, Reduced heat stress illness / deaths.
- **Mental health –** Greener environments promote wellbeing at home and at work.
- **Jobs –** Green infrastructure industry provides manufacturing and maintenance jobs.
- **Tourism –** A greener city will attract more visitors.
- **Urban food production –** Reliable, cheap food source close to market.

# Ecosystem Services

- '…the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life"

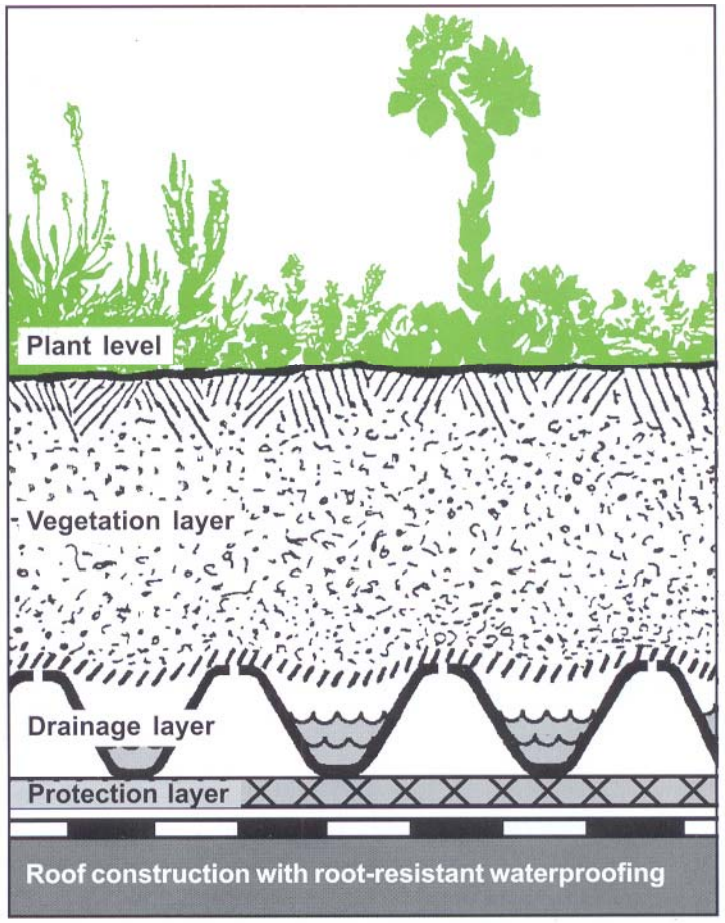
(Daily 1997)

- …" the benefits human populations derive, directly or indirectly, from ecosystem functions"

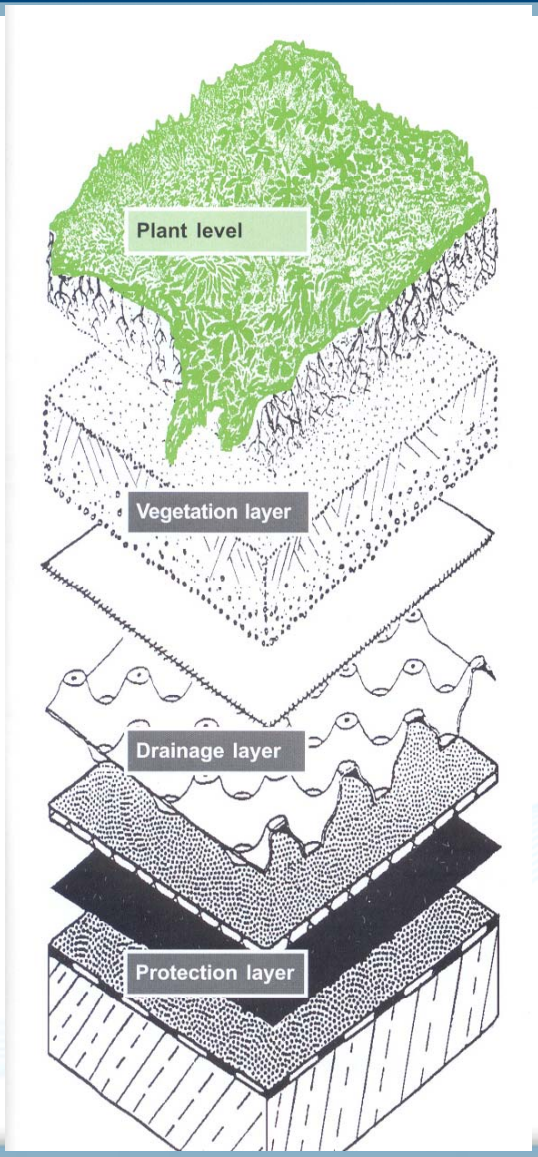
(Constanza et al 1997)

# Green roofs

| Weight kg/m² | | Height mm |
|---|---|---|
| dry | water-saturated | |
| 80 | 96 | 70 |
| 2 | 9 | 30 |
| 82 | 105 | |




| | | |
|---|---|---|
| Build-up height: | approx. | 100 mm |
| Wet weight, incl. plants: | approx. | 95 kg/m² |
| Retention capacity: | approx. | 23 l/m² |



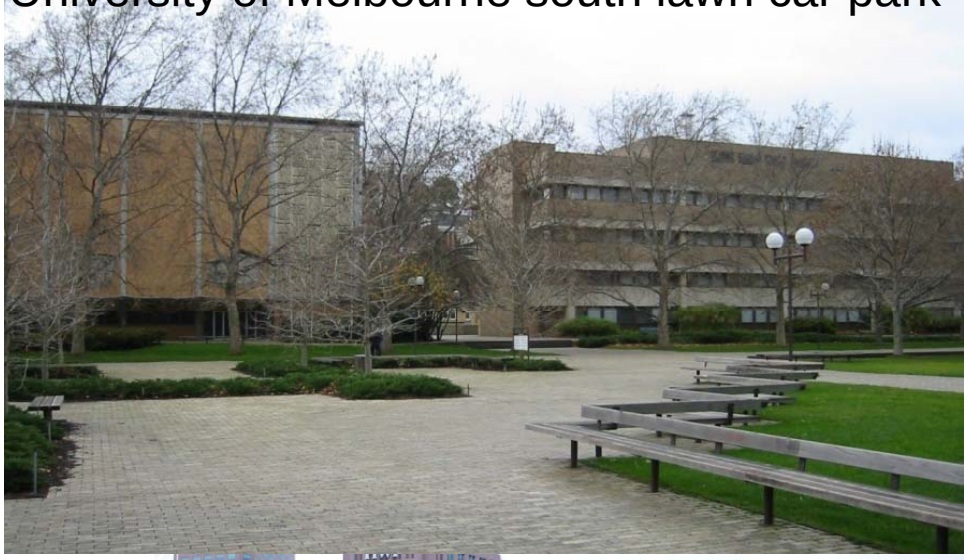
# Types of Green Roofs – intensive

- relatively nutrient rich, deep substrate (> 20 cm)
- allows for establishment of greater range of plants, trees, shrubs and conventional lawns.
- require higher levels of maintenance, regular irrigation and applications of fertiliser
- weight can be considerable requiring substantial reinforcement of an existing roof or extra building structural support.

# Intensive green roofs: public space

Parliament House, Canberra

University of Melbourne south lawn car park

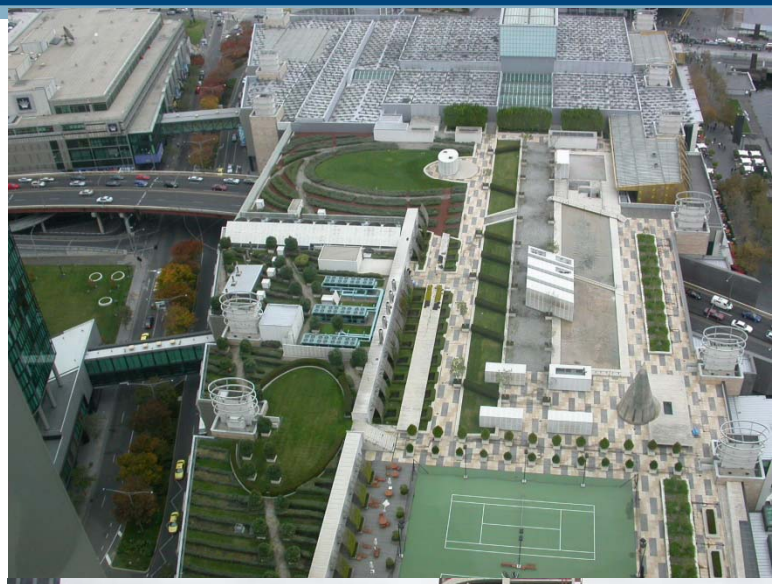


NGV International Sculpture Garden

**Dr Nick Williams, Melbourne School of Land & Environment**

# Intensive green roofs: apartments

M Central, Sydney



FreshW*ater* Place, Melbourne
Fytogreen 350 mm irrigated profile

Crown Casino, Melbourne

# Intensive green roofs: Sustainable Office Buildings

CH2 Building, Melbourne

Intensive roof garden and 30 cm deep non irrigated modular semi extensive green roof

30 The Bond, Sydney

Marine Discovery Centre Queenscliff, 30 cm deep

# Types of Green Roofs – extensive

- Shallow, low-nutrient light substrates <20 cm
- low maintenance, usually no irrigation or fertilisation although it may be required initially
- Don’t provide as many amenity and recreation benefits
- Provide greater biodiversity benefits than intensive roofs, in Europe - ‘Ecoroofs’
- planted with, or colonised by, mosses, succulents, some wild flowers and grasses
- Very few in Australia

# Extensive Green Roofs


Roman Castle Museum, Essligen Germany


DHL Distribution Centre, Kongen, Germany


Ford Truck assembly plant, Dearborn Michigan – 4.1 ha (the worlds largest extensive green roof)

**Dr Nick Williams, Melbourne School of Land & Environment**

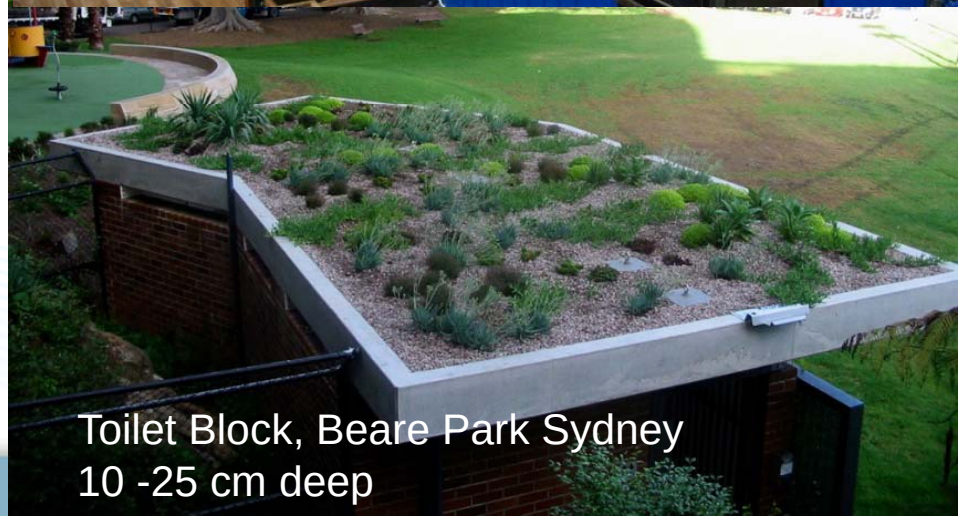
# Extensive Green Roofs

Rotherham Crofts U.K.

# Very Few Extensive Green Roofs in Australia

Experimental Green Roof Burnley Campus 12.5 cm deep

Venny Community Centre, Flemington. Built by City of Melbourne Oct 2009 10-15 cm deep



Toilet Block, Beare Park Sydney 10 -25 cm deep

**Dr Nick Williams, Melbourne School of Land & Environment**

# Projects under construction

Kingston School, Hobart.

Image: Hassell

Victorian Desalination Plant

Pixel Building, Melbourne

Image: Grocon

# Green Walls

Plants growing on walls

Two distinct approaches

- Façade Greening
  - Self clinging climbers
  - Twiners and tendril climbers
- Living Walls
  - Fabric based hydroponic systems
  - Cell / modular based irrigated systems
  - Planted stone and rock walls

# Façade Greening: self clinging

Tubingen Germany


BC Place Vancouver

# Façade Greening: tendril

- Need trellis or wire support systems

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# Modular Systems

Vancouver Airport


Moonee Ponds Waste transfer station

Wholefoods Vancouver

# Fabric based hydroponic

Musee du quai Branly, Paris


Melbourne Central

# Vegetated Urban Design

Footbridge, Stuttgart

Tramline Grenoble

# Benefits of Green Infrastructure

## Human Well Being

- Aesthetic and amenity
- Physical and mental health
- Localised food production

## Economic Benefits

- Insulation and energy efficiency
- Increased asset life (roofs, walls, roads)
- PR, worker productivity etc

## Environmental

- Stormwater management
- Air quality
- Biodiversity habitat
- Mitigating the Urban Heat Island effect

# Aesthetic and amenity

- Improves the view
- Can provide passive or active recreation space in dense areas otherwise lacking it
- Financial benefits to building owners, increased rent etc
- Makes apartment living more attractive, important in moving to higher density cities
-

# Health Benefits of Green Space

Modified from Table 2. Tzoulas et al 2007

| | |
|---|---|
| Innate need to contact biodiversity for psychological well being | Kellert & Wilson 1993 |
| Urban green spaces users have greater longevity | Takano *et al* 2002 |
| Urban green spaces users have better self reported health | De Vries *et al* 2002 |
| Natural views restore attention fatigue; and quicken recovery of attention-demanding cognitive performances | Kaplan & Kaplan 1989, Hartig 2003 |
| Natural views provide relaxation, increased positive self-reported emotions, and recovery from stress | Ulrich 1984, Ulrich et al 1991 |
| Children with ADD who are active in green spaces show reduced symptoms | Faber-Taylor et al. 2001 |
| Green views increase the effectiveness of people in facing major crises, and lessen aggression by reducing mental fatigue | Kuo 2001, Kuo & Sullivan 2001 |
| People visit favourite places, often natural settings, for regulation of self-experience and feelings | Korpela 1989, 1992, Korpela & Hartig 1996 |
| Natural features and open spaces in a residential area enhance sense of community | Kim & Kaplan 2004 |
| Urban park users reported better general perceived health, more physical activity and relaxation | Payne et al. 1998 |

# Health Benefits: Urban Heat Waves

- Heat waves in urban areas are a major threat to human life
  - 14,800 excess deaths in France, 35,000 in Europe during 2003 heatwave
  - 374 excess deaths in Melbourne January 2009
  - Majority, elderly people in cities
- exacerbated by the UHI effect
- urban residents can experience sustained thermal stress while rural people obtain relief at night

# Health Benefits: Urban Heat Waves

- Major risk factors in 2003 Paris heatwave:
  - Lack of mobility, pre-existing medical condition, living on the top floor, temperature around the building (Vandentorren *et al* 2006)
- Mitigation of UHI is a major public health benefit of urban vegetation
- Little is known about the effectiveness of urban planning measures for human health, but urban planning has an important role in primary prevention (WHO).

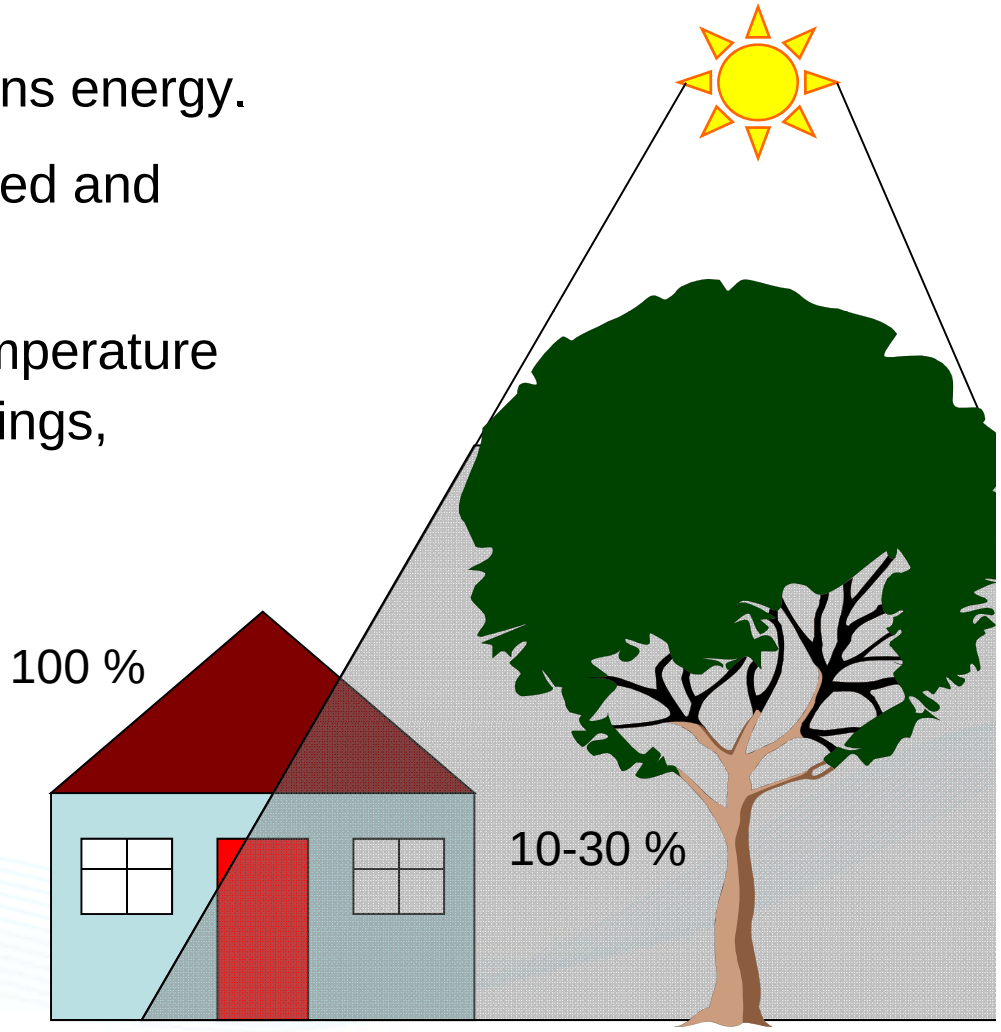
# Localised Food Production

- Opportunity to grow food in high density urban environments
- Reduce food miles
- Social benefits

# Energy Benefits: Street Trees

## Shade cooling

- Trees can intercept majority of suns energy.
- Some is reflected, most is absorbed and used in photosynthesis.
- Tree canopies can reduce the temperature of surfaces they shade (e.g. buildings, roads) by **10-25°C**.

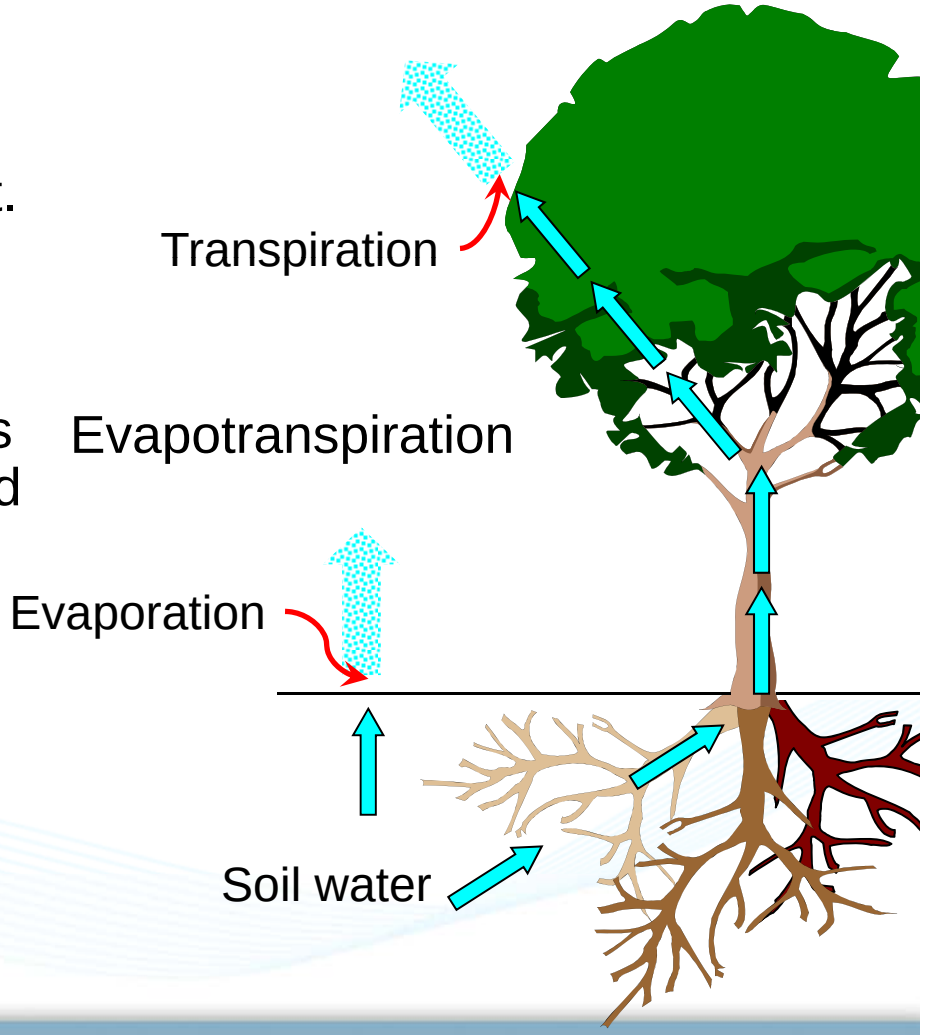



*Akbari et al., 1997. Energy & Buildings*

# Energy Benefits: Street Trees

## Evapotranspiration cooling

- Converting liquid to gas uses heat.
- Reducing the temperature of the air and the tree/soil that stored that heat.
- Plants and soil must have water to enable evapotranspiration cooling.
- Otherwise, heat is released slowly as sensible heat through conduction and convection.
- Leafy suburbs can be 2-3°C cooler than new, leafless suburbs




*Wong et al., 2008. US EPA Reducing urban heat islands*

# Energy Benefits: Green Roofs

- Insulating effect of substrate reduces penetration of summer heat and escape of winter heat
  - In Singapore green roof transferred 10% of the heat of a control roof
  - In Ottawa, 95% reduction in heat gain, 26% reduction in heat loss. 75% saving in energy
- Some studies have suggested lower saving in regions with a Mediterranean climate
- Preliminary modelling results from Burnley green roof suggest
  - 48% reduction in summer cooling load
  - 13% reduction in winter heating load

# Energy Benefits: Green Roofs

Figure 4: Temperature Differences between a Green and Conventional Roof


On a typical day, the Chicago City Hall green roof measures almost 80°F (40°C) cooler than the neighboring conventional roof.

- Increased insulation (relatively small, a few %)
- Cooling (reducing with about 30%, range: 6-49% )
- Increased roof life expectancy

*e.g. :*
*Saiz et al. (2006) – Env. Sci. Technol. 40: 4312-4316 ;*
*Getter & Rowe (2006) – HortScience 41:1276-1285*

# Pollution Benefits: Street Trees

## Pollution Removal by Chicago's trees

- Chicago has 11% tree cover
- In 1991 trees removed an estimated
  - 212 tons of particulates (PM10)
  - 15 tons of CO
  - 84 tons SO2
  - 89 tons NO2
  - 191 tons of O3
- Varies seasonally

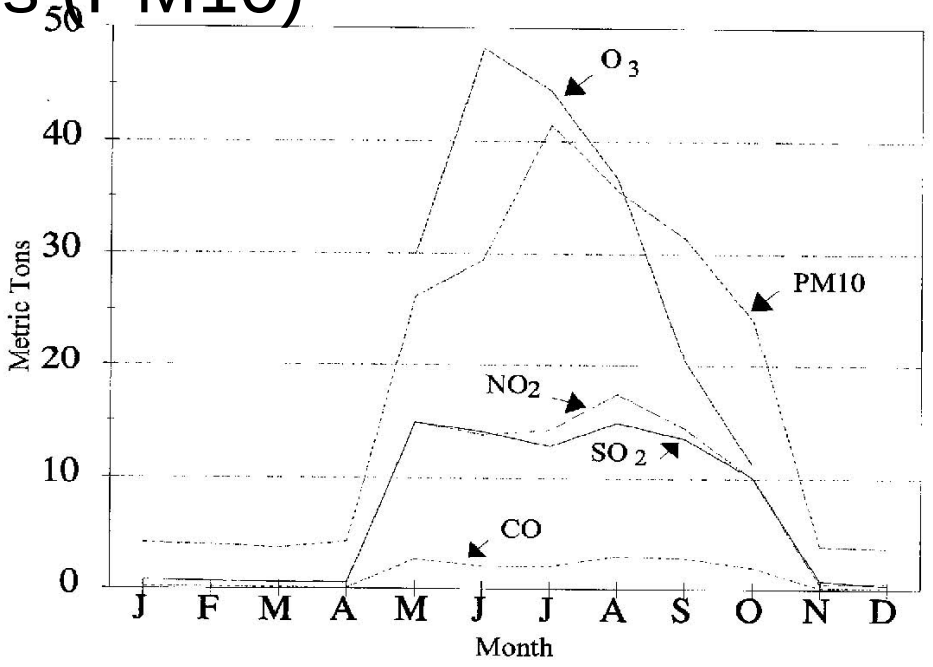



Figure 7. —Monthly estimates of pollution removal by trees in Chicago in 1991. Ozone removal estimates are for May-October only. Particulate removal assumes 50 percent resuspension back to the atmosphere.

# Pollution Removal by Chicago's trees

- Value of air pollution removal by trees across the Chicago region is estimated to be $9.2 US Million
  - Measured using emission control costs
  - Each large tree removes $2.31 of pollution / year
- Large healthy trees remove an estimated 60-70 times more pollutants than small trees
  - It is important to sustain healthy large trees

# Pollution Removal by US urban trees

**Table 3.** Air pollution removal and value for all urban trees in the coterminous United States

| Pollutant | Removal (t) | Value ($ × $10^6$) |
|---|---|---|
| $O_3$ | 305,100 (75,000–390,200) | 2,060 (506–2635) |
| $PM_{10}$ | 214,900 (84,000–335,800) | 969 (378–1514) |
| $NO_2$ | 97,800 (42,800–119,100) | 660 (289–804) |
| $SO_2$ | 70,900 (32,200–111,100) | 117 (53–184) |
| CO | 22,600 na | 22 Na |
| Total | 711,300 (256,600–978,800) | 3828 (1,249–5158) |

Values vary due to:

- Tree cover
- Pollution levels
- Length of leaf season
- Annual rainfall

# Stormwater Benefits: Street Trees

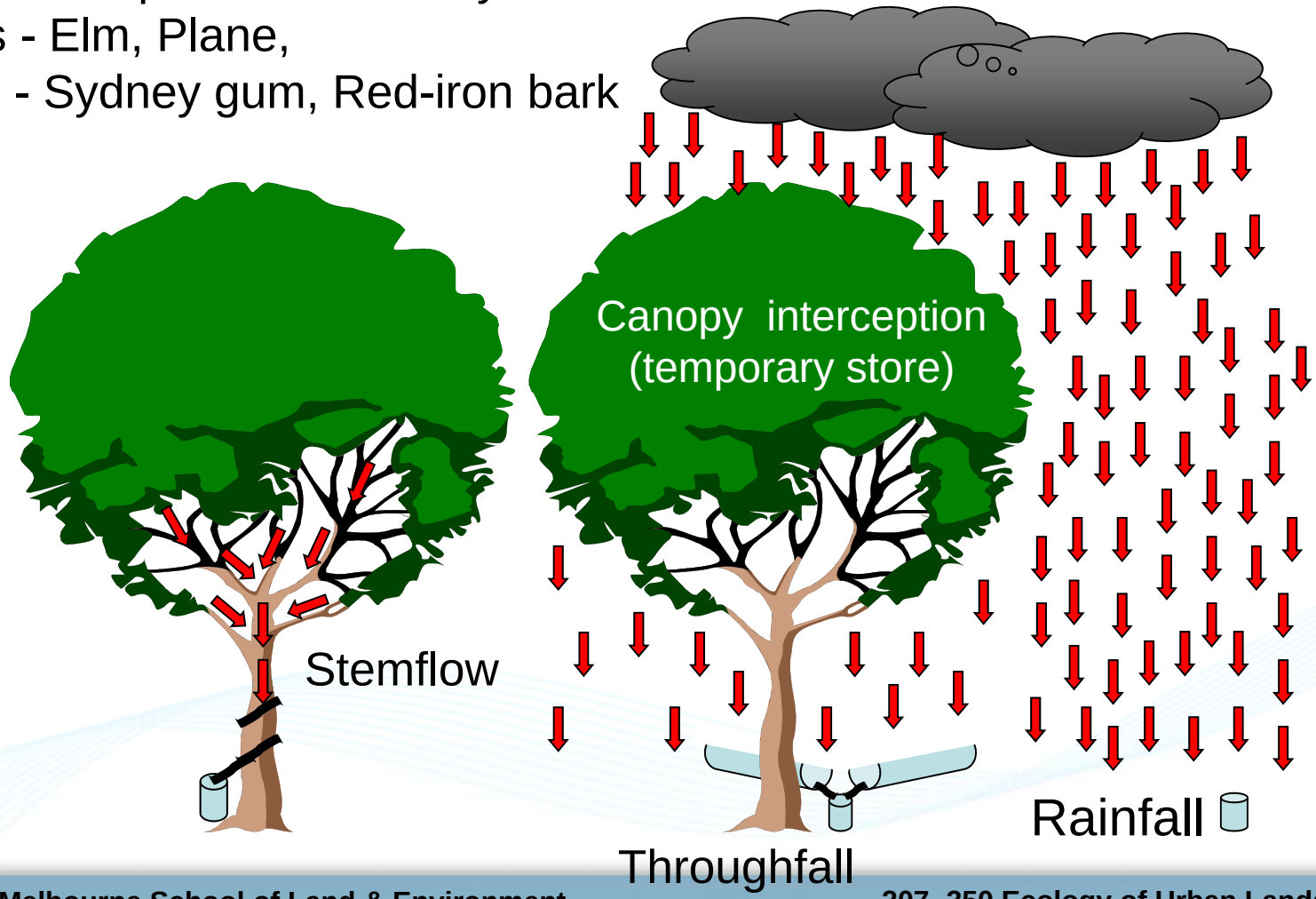
Some rainfall intercepted by a canopy can be temporarily stored, and then gradually enter the soil system or evaporate into the atmosphere.

Reduces storm water run-off, and peak discharge into:
i) sewerage systems &
ii) natural waterways.

This reduces flooding and maintains stream ecological integrity

# Stormwater Benefits: Street Trees

Studying 4 tree species at Burnley:
Deciduous - Elm, Plane,
Evergreen - Sydney gum, Red-iron bark

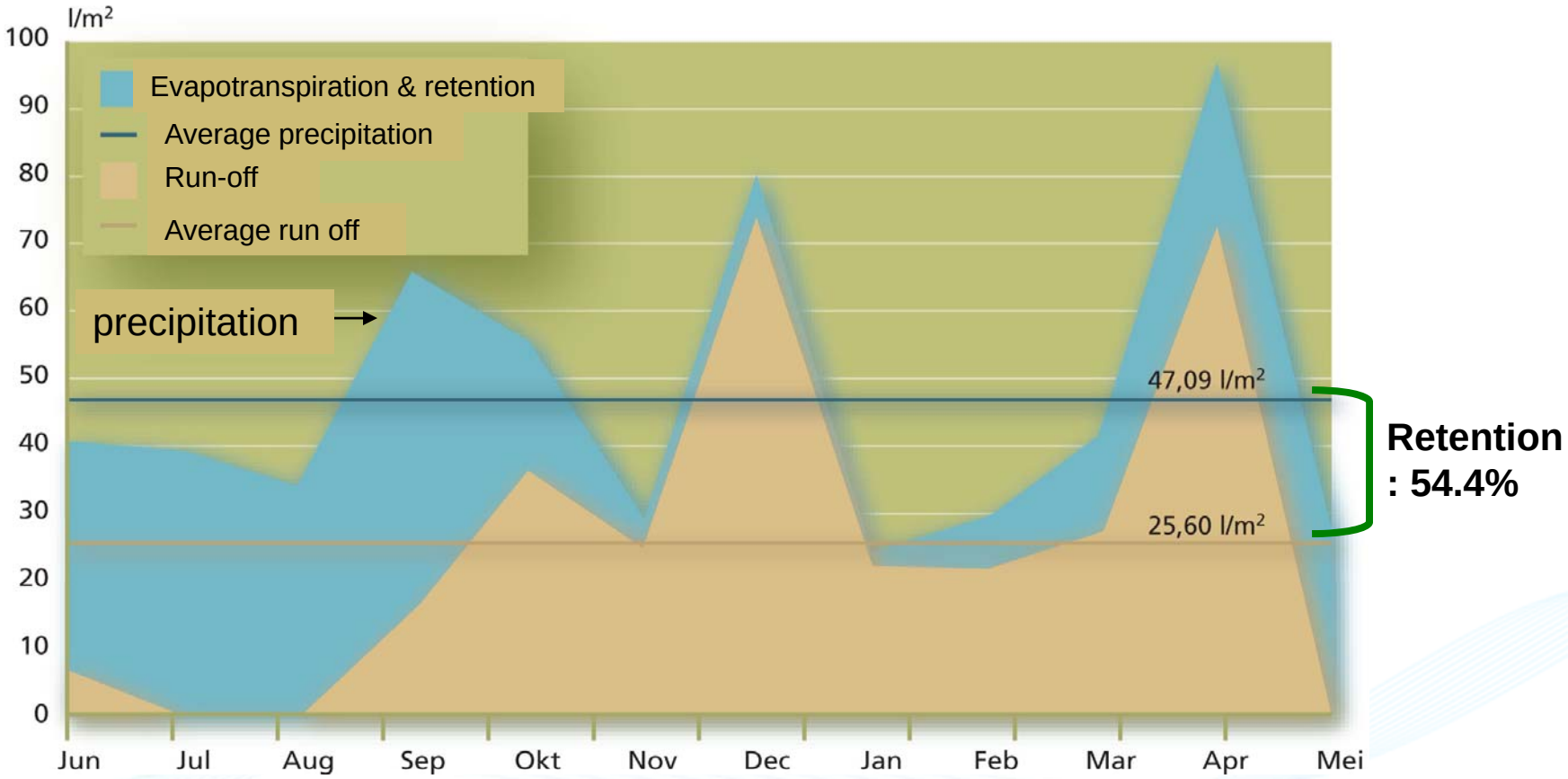


# Stormwater Benefits: Green Roofs

- Green roofs are a WSUD measure that does not require additional space
- Substantially decrease quantity and improve quality of stormwater
- The deeper the substrate depth, the greater the reduction in runoff

# Stormwater Benefits: Green Roofs

– Water retention function → **reducing run-off**



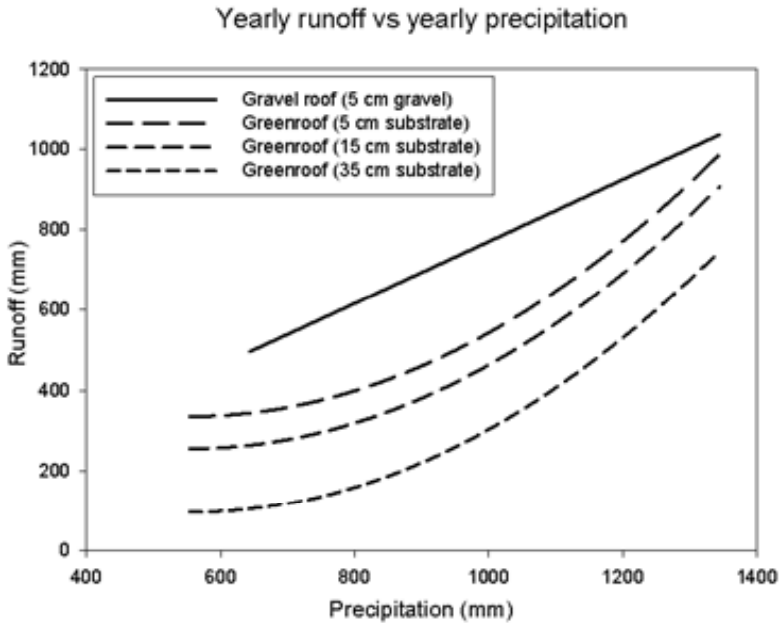

Evapotranspiration on 11 extensive green roofs (subst. 5-14cm)

Run-off in mm/ 5 min

Conventional roof

Ext green roof (5cm substr)

– Water retention function: reduces & slow down peak discharges, but depends on total precipitation




Run-off intensity in mm/hr

Time (5 mins)

Conventional roof

Ext green roof (5cm substr)

*Mentens et al. (2006)- Landsc.Urban Plan. 77: 217-226*

# Biodiversity Habitat: Green Roofs

- Habitat for birds, insects, lizards
- Value is vegetation dependent
- Provide habitat for common species, and valuable stepping stones for birds and insects.
- Many extensive green roofs in Europe are designed for biodiversity
  - Basel's biodiversity strategy makes green roofs mandatory on new buildings with flat roofs and provides guidelines to create different habitats on green roofs
  - Black Redstart, rare UK bird of brownfield sites. Developers have to recreate habitat on roofs

# Barriers to using green infrastructure in Australia

- Lack scientific data available to evaluate applicability to Australian conditions.
- Relying on northern hemisphere experience and technology is problematic due to significant differences in rainfall, temperature, available substrates and vegetation.
- Can introduce unacceptable risk and increase green roof/wall project costs
- Basic research needed to objectively evaluate the performance, cost and environmental benefits of green infrastrcuture in Australia

# Barriers to using green infrastructure in Australia

- Young inexperienced green roof /wall industry
  - Costs initially higher
  - Lack of integrated supply chain
- Minimal inclusion in green star rating schemes
- Lack of standards and design guidelines
- Few demonstration projects to give confidence to developers

# Burnley Experimental Green Roof

# Green Roof Research @ The University of Melbourne

- Established a 20 $m^2$, 125 mm deep experimental unirrigated green roof

Using it to:

1. Select plants that will survive and look good in Australian climatic conditions
   - Plant survival trials
   - Droughting trials
2. Develop locally produced light weight substrates
3. Investigate the effect of the green roof on building energy budgets

# Progress over time




# Results

- All individuals of 28 species dead by Mar 2009
  - All native herbs and grasses died
- 3 successful species: *Sedum x rubrotinctum, Sedum pachyphyllum, Oscularia deltoides*
- Trialing many more species
- Developed 3 green roof substrates based on:
  - Scoria
  - Bottom ash from power stations
  - Crushed recycled roof tiles

# Using results on new green roofs

- Monash Civic Centre
- The Venny
- Pixel Building
- Growing Up

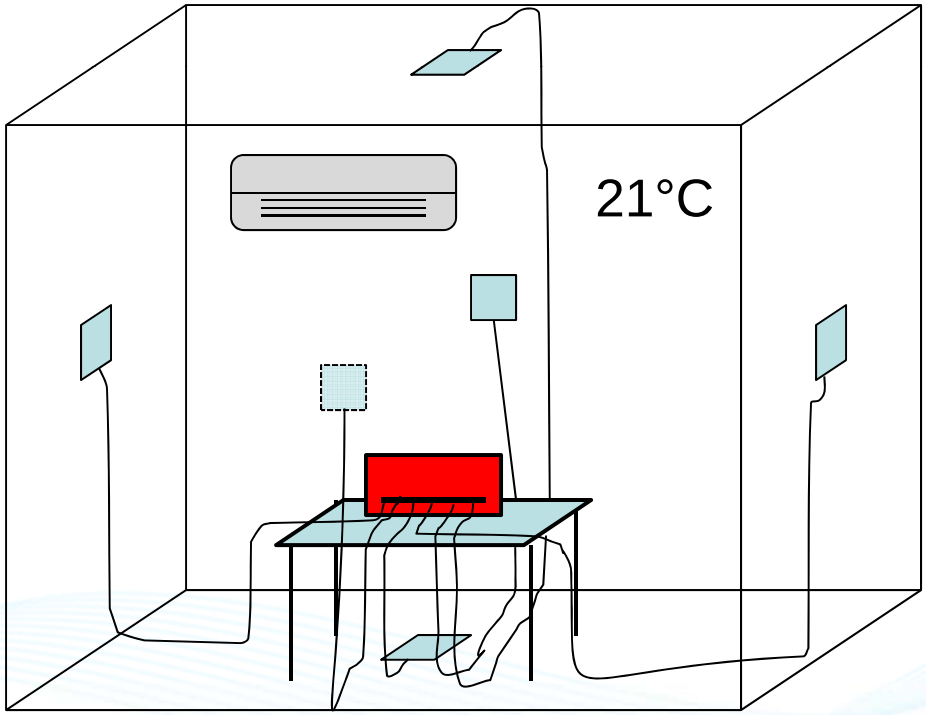
# Energy Saving Benefits of Trees

- Multidisciplinary Melb Uni project
- Funded by Nursery and Gardens Industry Australia

# Energy Saving Benefits of Trees

Heat flux sensors to measure the thermal load and transfer of heat into in summer (and out of in winter) the buildings

32°C



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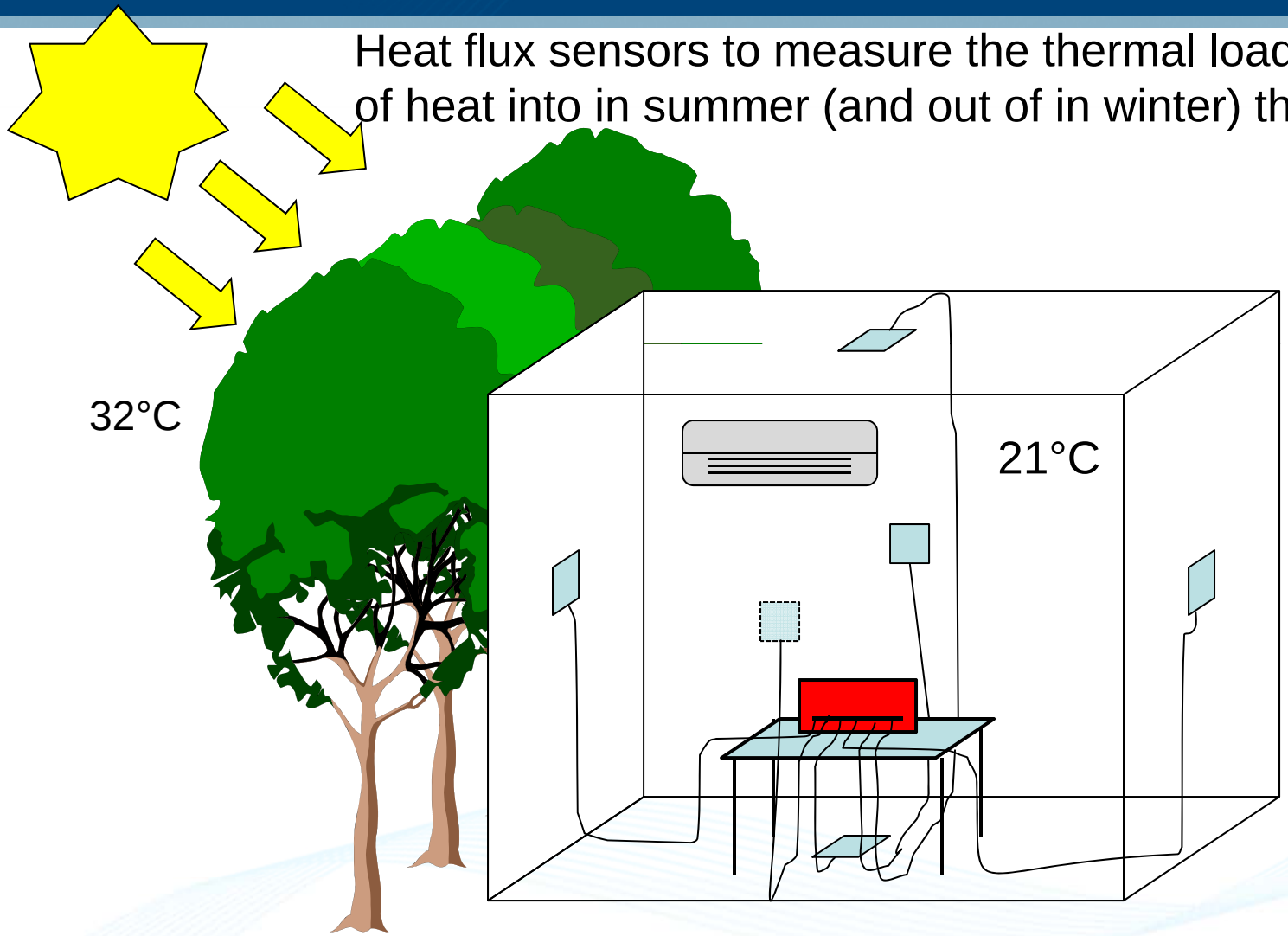

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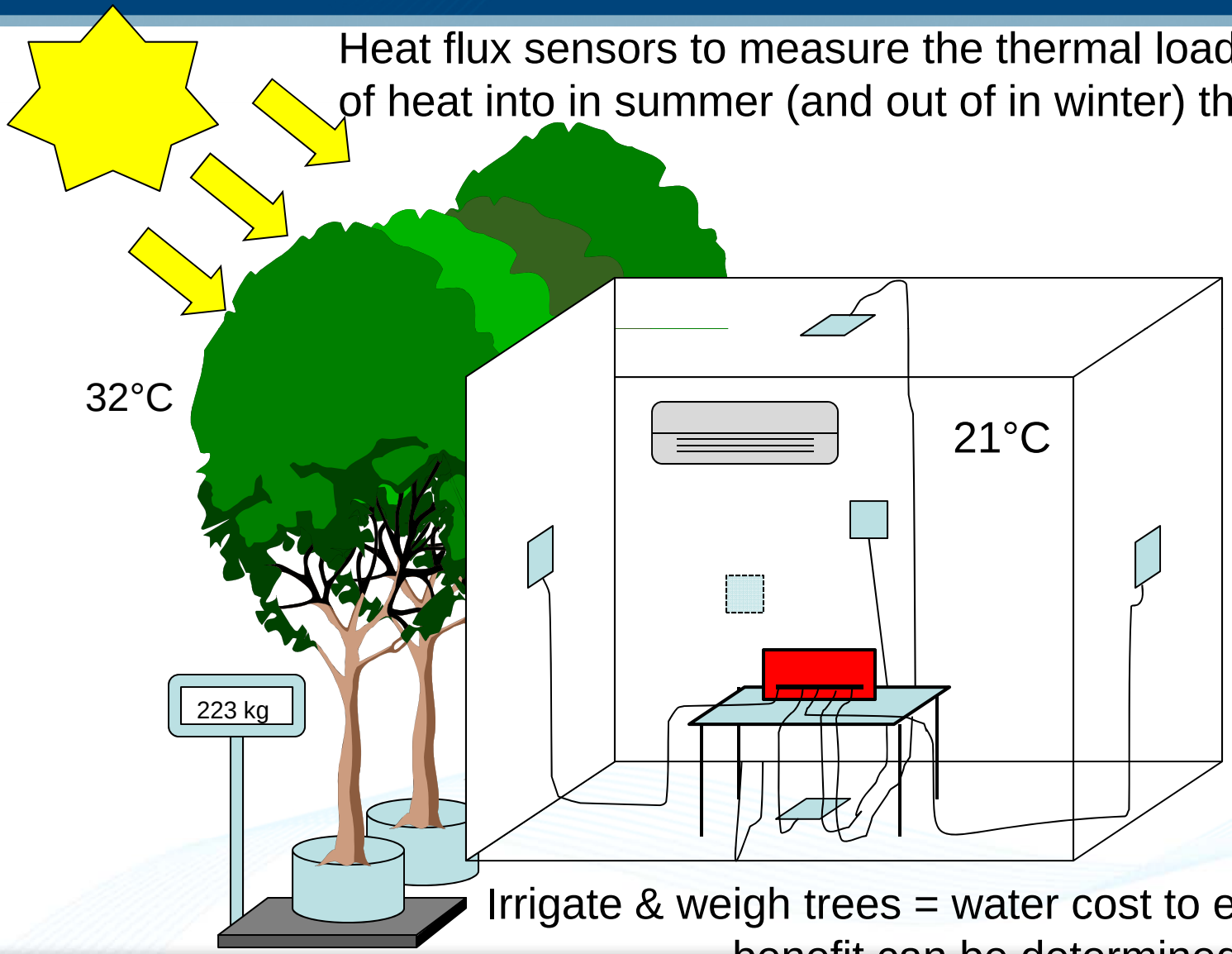


Irrigate & weigh trees = water cost to energy saving benefit can be determined

# Barriers to using green infrastructure in Australia

- Ignorance of urban water issues

"Green infrastructure is a valuable area of urban design, and might contribute to climate change adaptation. This proposal is written from the standpoint of someone who already knows that trees are beneficial for adaptation under climate change. However, it isn't so straightforward - it may in fact be argued to be a maladaptation, since more trees require more water, which may not be the right solution in a drying climate".

NCCARF Settlements and Infrastructure Science Review Panel

- May need integrated design solutions using grey water or storm water

# Green Infrastructure Adaptation Centre (GIAC) @ Burnley

## Demonstration, Education, Extension, Research